Quantitative estimation of Thermal Contact Conductance of a Graphite Filter Assembly

Mutsumi Sano[a], Sunao Takahashi[a], Tetsuro Mochizuki[a], Atsuo Watanabe[a] and Hideo Kitamura[a,b]

[a]JASRI/SPring-8、[b]RIKEN/SPring-8

< Introduction >

Thermal contact conductance (TCC) of Graphite Filter Assemblies (GFAs) were quantitatively estimated by consolidating the results of experiment and FEM analyses. The GFAs are general components which are installed to X-ray beam lines in synchrotron radiation facilities. At SPring-8 front ends, they work to cut the low-energy part of the synchrotron radiation so that the heat load on the beryllium windows is reduced. Because a graphite sheet of the GFA is indirectly cooled by the cooling holders, the actual TCCs between the graphite sheet and the cooling holder are indispensable to predict the maximum temperature of the GFA. Although it is well known that the TCC is influenced by many factors, we focused on the surface roughness of the contact areas, and interstitial materials in the present study.

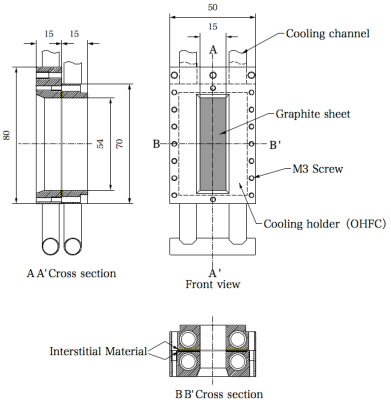
< Experiment >

The temperature drops between a heated part by the electron beam and a cooling part were measured near the interface.

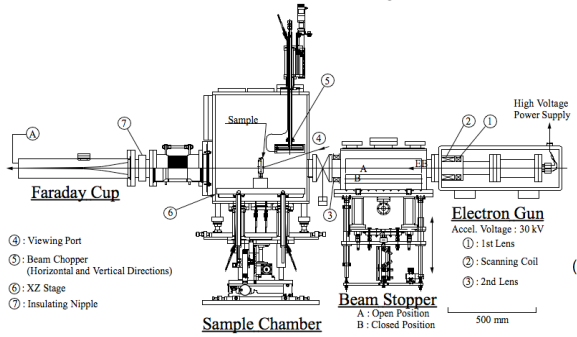
○ Experimental conditions

Absorbed power	300 W
Flow rate of the cooling water (downstream side only)	2 liter min^{-1}
Thickness of the graphite sheet	100 μm
Interstitial materimal	Au (50 μm) 、Au (20 μm) 、Ag (50 μm)、No interstitial material
Surface roughness (Ra)	1.6 μm、12.5 μm
Fastening torque	0.63 N m (Recommended torque for M3 bolt)

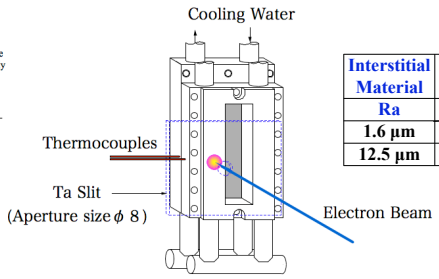
○ Graphite Filter Assembly



○ Electron beam irradiation system



○ Inside the Sample chamber



○ Temperature drops between the cooling holders

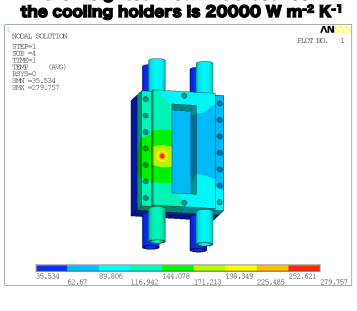
Interstitial Material / Ra	Au(50 μm)	Au(20 μm)	Ag(50 μm)	No Interstitial Material
1.6 μm	26.3~30.2 K	20.3~24.8 K	23.5~30.8 K	20.1~26.2 K
12.5 μm	25.0~33.4 K	18.6~25.2 K	22.7~30.4 K	18.9~29.7 K

< FEM analyses using *ANSYS* >

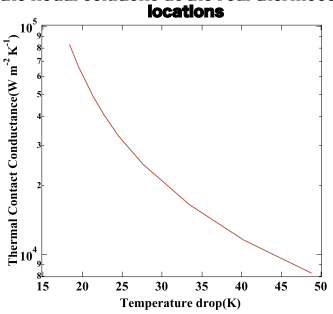
○ Boundary conditions

Absorbed power	300 W (The beam profile in the horizontal direction was fitted by a Gaussian distribution.)
Absorbed size	ϕ8 mm
Heat transfer coefficient of the cooling channel	3955 W m^{-2} K^{-1}
Temperature of the cooling water	33 ℃
TCC between the Graphite sheet and the Cooling holder	50000 ~ 500000 W m^{-2} K^{-1} (Reference area C)

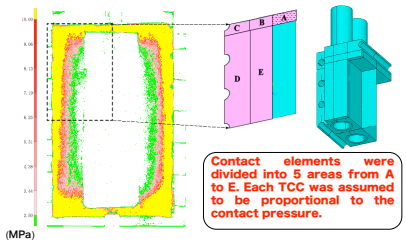
○ Temperature distribution when the weighted mean TCC between the cooling holders is 20000 W m^{-2} K^{-1}



○ The relationship between the weighted mean TCC and the temperature drop calculated from the nodal solutions at the real thermocouple locations

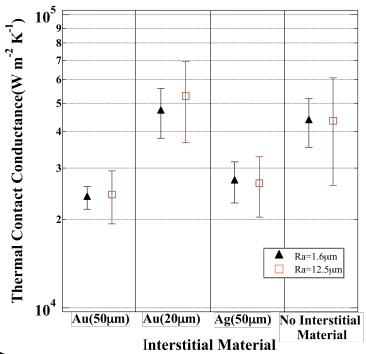


○ Pressure distributions of the contact area



Contact elements were divided into 5 areas from A to E. Each TCC was assumed to be proportional to the contact pressure.

< Weighted mean TCCs between the cooling holders for the various conditions >



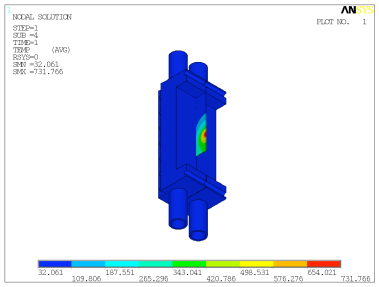
< Actual component >

○ Maximum temperature of the GFA at BL3 7XU in SPring-8

○ Boundary conditions

Absorbed power	94 W (Minimum Gap: 8 mm, Absorbed size: ϕ4)
Weighted mean TCC between the cooling holders	20000 W m^{-2} K^{-1}
Heat transfer coefficient of the cooling channel	3955 W m^{-2} K^{-1} (Flow rate: 2 liter min^{-1}, Diameter: ϕ8)
Temperature of the cooling water	33 ℃

○ Temperature distribution of the GFA at BL37XU



< CONCLUTIONS >

1. We confirmed that the weighted mean TCC for the GFA could be assumed to be at least greater than 20000 W m^{-2} K^{-1}.
2. The standard deviations for the rougher surfaces (Ra=12.5 μm) are larger than those for the smoother ones (Ra=1.6 μm).
3. The thicker interstitial material (50 μm) possibly leads to worse contact condition.
4. The maximum temperature of the GFA is calculated to be 731℃ in the case of BL37XU.